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P2.25: Design of a High Power W-Band Maser based on a Two Dimensional Periodic Structure

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Abstract: *High power millimetre-wave sources operating in the W-band (75GHz-110GHz) frequency range are important for a number of applications. This work will focus on the design and construction of a high power maser operating in the W-band frequency range, which can be capable of generating spatially and temporally coherent radiation at a power of at least 10 MW.*

Keywords: Cherenkov; high power; W-Band; millimetre-wave; oversized; periodic structure; induced feedback.

Introduction

In order to generate high levels of power, an electron beam that is oversized, with respect to the wavelength of operation, may be used. This allows any problems associated with high electromagnetic power density; such as electric field breakdown inside the interaction space, to be overcome. A periodic structure can be utilized as the feedback mechanism when an oversized beam is used [1-3]. The periodic lattice is in the from of a two dimensional corrugated structure which acts to synchronise the radiation from different parts of the annular electron beam, while at the same time ensuring spatial and temporal coherence of the radiation. The design and simulation of a W-band maser, which is driven by an oversized annular electron beam and where the interaction region is in the form of a periodic lattice, is presented here. The dependence of the maser's operation with driving electron beam current, as well as guiding magnetic field, are considered, with results presented and discussed. Analysis of the depth of corrugation on maser performance is also studied.

Study of a Cherenkov Maser

Numerical studies of a Cherenkov Maser have been carried out in order to maximize the achievable output power of such a device. This is achieved by means of optimizing various design parameters, including the guide magnetic field, electron beam current, and depth of corrugation. Numerical simulations are performed using the 3D Particle in Cell code MAGIC, where the maser design is based on a cylindrical waveguide with a doubly periodic corrugation inserted at the walls, fig. 1. The radius of the cavity is 1cm and the length of the interaction region is 6.4cm. The maser is immersed in a uniform guide magnetic field and is driven by a 100A electron beam, of radius 0.86cm, having single particle energy of 300kV and a pulse length of 10ns. The electron beam propagates through the interaction region and is dumped using a coil at the end of the interaction space, fig. 1. Let it be noted that this numerical work is constructed for one azimuthal period of corrugation only.

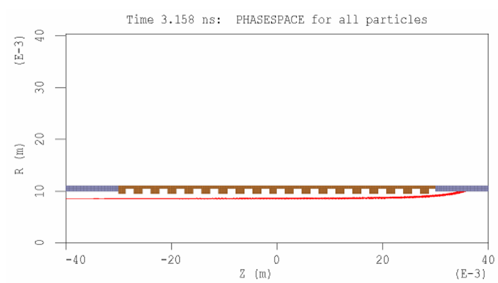


Figure 1. Longitudinal cross sectional view of the Cherenkov Maser showing the electron beam interacting with the structure to generate radiation.

Numerical Results

Variation of structure depth: The first case considered was a variation in magnetic field amplitude. This was varied from 0.5 to 8 Tesla in steps of 0.5T. Results show the operating frequency to be ~91.3GHz, fig. 2. The variation in power generated with magnetic field amplitude is shown by fig. 3. Maximum production of power was achieved when the magnetic field amplitude was set to equal 6 Tesla, corresponding to an output of approximately 23MW, fig. 3.

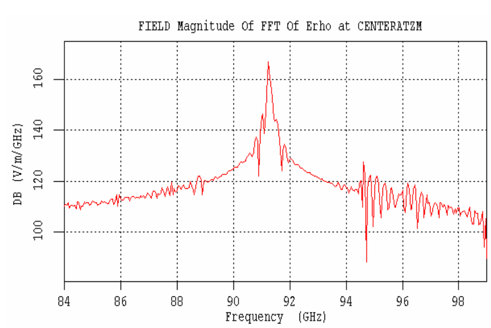


Figure 2. Output spectrum of the Cherenkov maser operating at a frequency of ~91.3GHz.

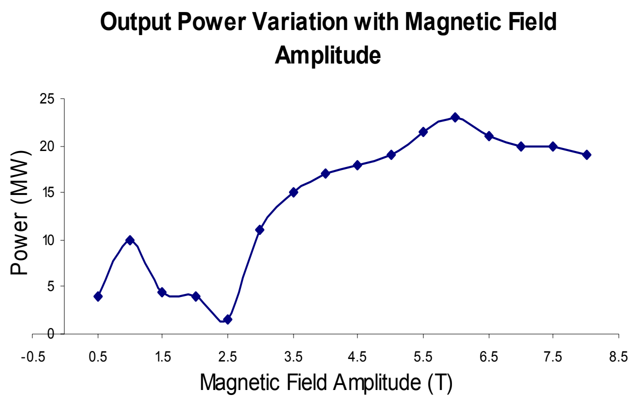
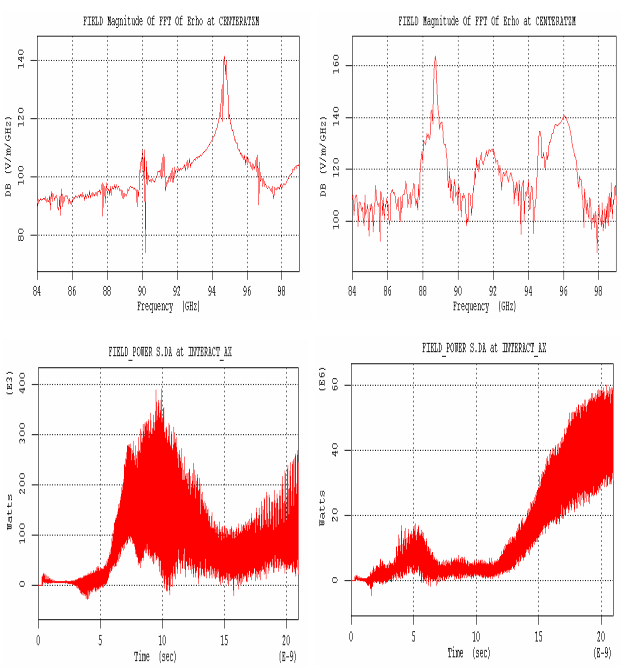


Figure 3. Plot relating the radiation power to the strength of the applied magnetic field.

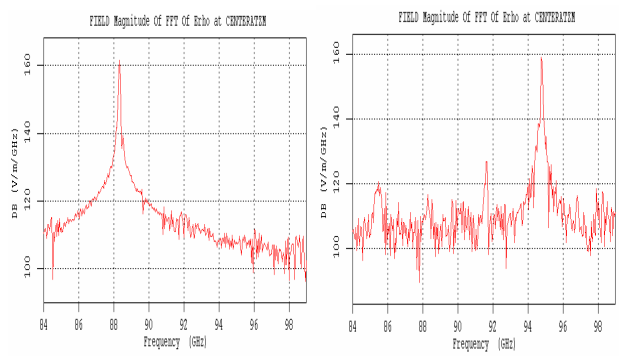
Variation of Electron Beam Current: Numerical work involving the electron beam current dependence was also examined. The current was varied from 25A to 200A in steps of 25A, with the magnetic field amplitude fixed at 6 Tesla. Application of a 25A electron beam resulted in the production of ~0.2MW output power at the single frequency of ~94GHz, fig 4a. This is in contrast to the case when a 200A beam is used, which generates ~60MW as a result of the excitation of several frequencies in the range 88 – 97GHz, fig. 4b.



(a) **(b)**

Figure 4. Results of numerical studies into a Cherenkov Maser when driven by an electron beam having current a) 25A , and b) 200A.

Variation of structure depth: Simulations corresponding to various depths of corrugation from 0.8 – 1.2mm were also considered and were conducted using the optimum magnetic field amplitude value of 6 Tesla. Initial results indicate there is a general increase in power generation as the depth of corrugation is increased. In addition to this, there was also a variation in the frequency of operation, with an output of ~88GHz occurring when the depth of 0.8mm is used, fig. 5a, in comparison to a depth of 1.2mm which operates at ~95GHz, fig. 5b.



(a) **(b)**

Figure 5. Results showing the spectrum of output radiation produced by the Maser as operated using a corrugation depth of a) 0.8mm and, b) 1.2mm.

Future work will involve further study and analysis of the Cherenkov maser prior to the construction of an experiment.

References

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